Q1) what is orifice meter or orifice plate? Explain with neat sketch

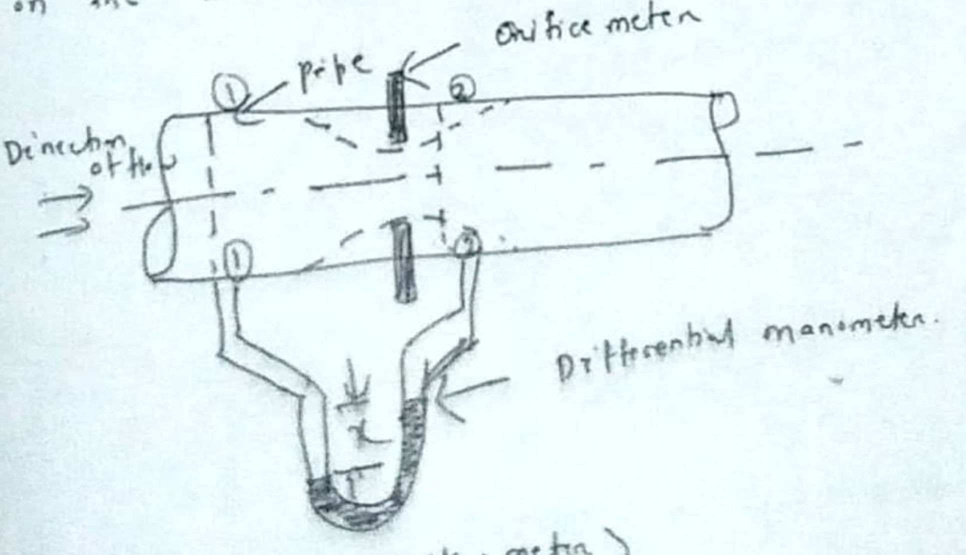
Orifice meter or Orifice plate :-

→ It is a device used for measuring the rate of flow of a fluid through a pipe. It is a cheaper device as compared to venturimeter. It also works on the same principle as that of venturimeter.

→ It consists of a flat circular plate which has a circular sharp edged hole called orifice, which is concentric with the pipe.

→ The orifice diameter is kept generally 0.5 times the diameter of the pipe, though it may vary from 0.4 to 0.8 times the pipe diameter.

→ A differential manometer is connected at section (1), which is at a distance of about 1.5 to 2.0 times the pipe diameter upstream from the orifice plate, and at section (2), which is at a distance of about half the diameter of the orifice on the downstream side from the orifice plate.



(figure - orifice meter)

Let P_1 = pressure at section (1),

v_1 = velocity at section (1),

a_1 = area of pipe at section (1), and

P_2, v_2, a_2 are corresponding values at section (2), Applying Bernoulli's equation at sections (1) and (2), we get

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

or $$\left(\frac{P_1}{\rho g} + z_1\right) - \left(\frac{P_2}{\rho g} + z_2\right) = \frac{v_2^2}{2g} - \frac{v_1^2}{2g}$$

But $\left(\frac{P_1}{\rho g} + z_1\right) - \left(\frac{P_2}{\rho g} + z_2\right) = h$ = Differential head

$\therefore$ $h = \frac{v_2^2}{2g} - \frac{v_1^2}{2g}$ or $2gh = v_2^2 - v_1^2$

or $$v_2 = \sqrt{2gh + v_1^2} \quad \text{——— (i)}$$

Now section (2) is at the vena-contracta and a_2 represents the area at the vena-contracta. If a_0 is the area of orifice then, we have, $C_c = \frac{a_2}{a_0}$

where C_c = coefficient of contraction

$\therefore$ $$a_2 = a_0 \times C_c \quad \text{——— (ii)}$$

By continuity equation, we have

$$a_1 v_1 = a_2 v_2 \text{ or } v_1 = \frac{a_2 v_2}{a_1} = \frac{a_0 C_c}{a_1} v_2 \text{ — (iii)}$$

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Substituting the value of v_1 in equation (i), we get

$$v_2 = \sqrt{2gh + \frac{a_0^2 C_c^2 v_2^2}{a_1^2}}$$

or $\quad v_2^2 = 2gh + \left(\frac{a_0}{a_1}\right)^2 C_c^2 v_2^2$ or $v_2^2\left[1-\left(\frac{a_0}{a_1}\right)^2 C_c^2\right] = 2gh$

$$\therefore \quad v_2 = \frac{\sqrt{2gh}}{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2 C_c^2}}$$

$\therefore$ The discharge $Q = v_2 \times a_2 = v_2 \times a_0 C_c$

$$= \frac{a_0 C_c \sqrt{2gh}}{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2 C_c^2}} \quad \text{——(iv)}$$

The above expression is simplified by using

$$C_d = C_c \frac{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2}}{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2 C_c^2}}$$

$$\therefore \quad C_c = C_d \frac{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2 C_c^2}}{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2}}$$

Substituting this value of C_c in equation (iv), we get

$$Q = a_0 \times C_d \frac{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2 C_c^2}}{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2}} \times \frac{\sqrt{2gh}}{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2 C_c^2}}$$

$$= \frac{C_d a_0 \sqrt{2gh}}{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2}} = \frac{C_d a_0 a_1 \sqrt{2gh}}{\sqrt{a_1^2 - a_0^2}}$$

where C_d = coefficient of discharge for orifice meter.
which is much smaller than that for a venturimeter.

Q// What is Pitot tube ? Derive the formula to measure the parameter it is used for.

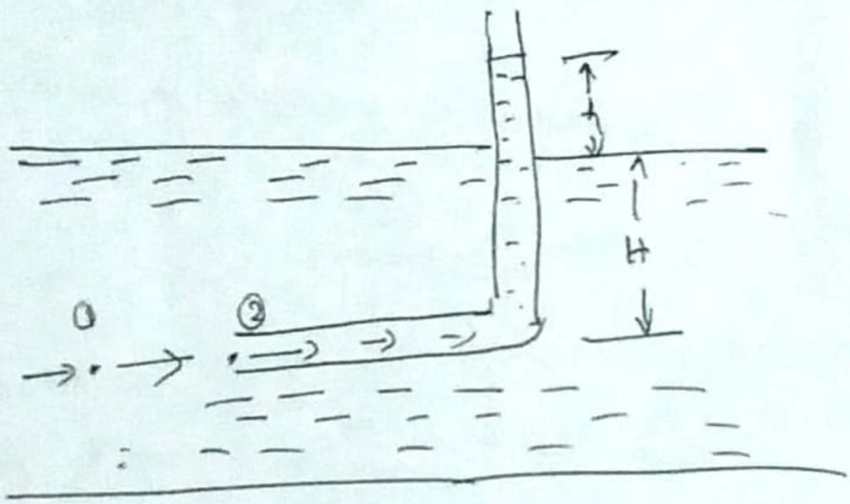
Pitot-tube

[BPUT 1st sem 2018-19]

→ It is a device used for measuring the velocity of flow at any point in a pipe or a channel.

→ It is based on the principle that if the velocity of flow at a point becomes zero, the pressure there is increased due to the conversion of the kinetic energy into pressure energy.

→ In its simplest form, the pitot-tube consists of a glass tube, bent at right angles as shown in the figure.



(Figure- pitot-tube)

→ The lower end, which is bent through 90° is directed in the upstream direction as shown in the figure. The liquid rises up in the tube due to the conversion of kinetic energy into pressure energy.

→ The velocity is determined by measuring the rise of liquid in the tube.

→ Consider two points (1) and (2) at the same level in such a way that point (2) is just as the inlet of the pitot-tube and point (1) is far away from the tube

Let p_1 = intensity of pressure at point (1)

v_1 = velocity of flow at (1)

p_2 = pressure at point (2)

v_2 = velocity at point (2), which is zero

H = depth of tube in the liquid

h = rise of liquid in the tube above the free surface

Applying Bernoulli's equation at points (1) and (2), we get

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

But $z_1 = z_2$ as points (1) and (2) are on the same line and $v_2 =$

$\frac{p_1}{\rho g}$ = pressure head at (1) = H

$\frac{p_2}{\rho g}$ = pressure head at (2) = $h + H$

Substituting these values, we get

$$H + \frac{v_1^2}{2g} = h + H \quad \therefore \quad h = \frac{v_1^2}{2g} \quad \text{or} \quad v_1 = \sqrt{2gh}$$

This is theoretical velocity. Actual velocity is given by

$$(V_1)_{actual} = C_v \sqrt{2gh}$$

where C_v = coefficient of pitot-tube

$\therefore$ velocity at any point $V = C_v \sqrt{2gh}$

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